



# **Next Generation Air Transportation System Air Traffic Management - Airspace Overview**

**Air Traffic Control Seminar**

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**Principal Investigator**

**NGATS ATM-Airspace Project**

**September 5, 2007**

# Outline



- **Background**
- **Project Overview**
- **Project Elements**
- **Project Growth Areas**



# Evolution of Control

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## Procedural Based Control



- Radio
- Landmark Navigation

## Surveillance Based Control



- Radio
- Radio Navigation
- Radar
- Gen 2 Computers

## Trajectory Based Control



- Flight Computers
- RNAV
- Satellite Navigation
- Digital Communication
- Radar
- Radio
- Gen X Computers

# NGATS ATM- Airspace Project



The NGATS ATM-Airspace Project will explore and develop concepts, and integrated solutions providing research data and analyses to define and assess automation concepts and technologies necessary for the Next Generation Air Transportation System.



# NGATS - ATM Airspace Research Thrusts

## (Research Focus Areas)



- **Fundamental research purpose: address demand/ capacity imbalance problem in the most safe, equitable, and efficient manner**
  - *Dynamic Airspace Configuration* strives to increase capacity through dynamic allocation of airspace structure and controller resources
  - *Traffic Flow Management* works to effectively allocate demand through departure times (+/-), route modification, adaptive speed control,...etc., in the presence of uncertainty
  - Reduce capacity-limiting impact of human-controlled separation assurance
    - *Separation Assurance* (sequential processing of sequence and merging with separation) for transition and cruise airspace
    - *Airspace Super Density Operations* (simultaneous sequencing, spacing, merging, and de-confliction) for terminal airspace
- **Cross-cutting elements to support the functional thrusts**
  - Accurate trajectory predictions that are interoperable with aircraft FMS trajectory generations using prediction uncertainty growth and propagation (*Trajectory Prediction, Synthesis, and Uncertainty*)
  - Research on the performance-enhancing effect of emerging airborne technologies on solutions to the fundamental ATM problem (*Performance Based Services*)
  - System design and analysis tool development to assess the functional/temporal distribution of authority and responsibility among/between automation and humans (*System-Level Design, Analysis and Simulation Tools*)

# What is it all about?



- **Precision**
- **Prediction**
- **Satisfaction**

# Airspace Project – Research Area

## Dynamic Airspace Configuration



### Problem

- Static homogenous rigid airspace structure
- Limited degrees of freedom (e.g., combine two adjoining sectors)
- Substantial time to modify airspace (years) and train controllers (months)

### Expected Impact or End Result

- Development of concepts and technologies that define airspace tailored to demand
- Near-term “user” influenced airspace design

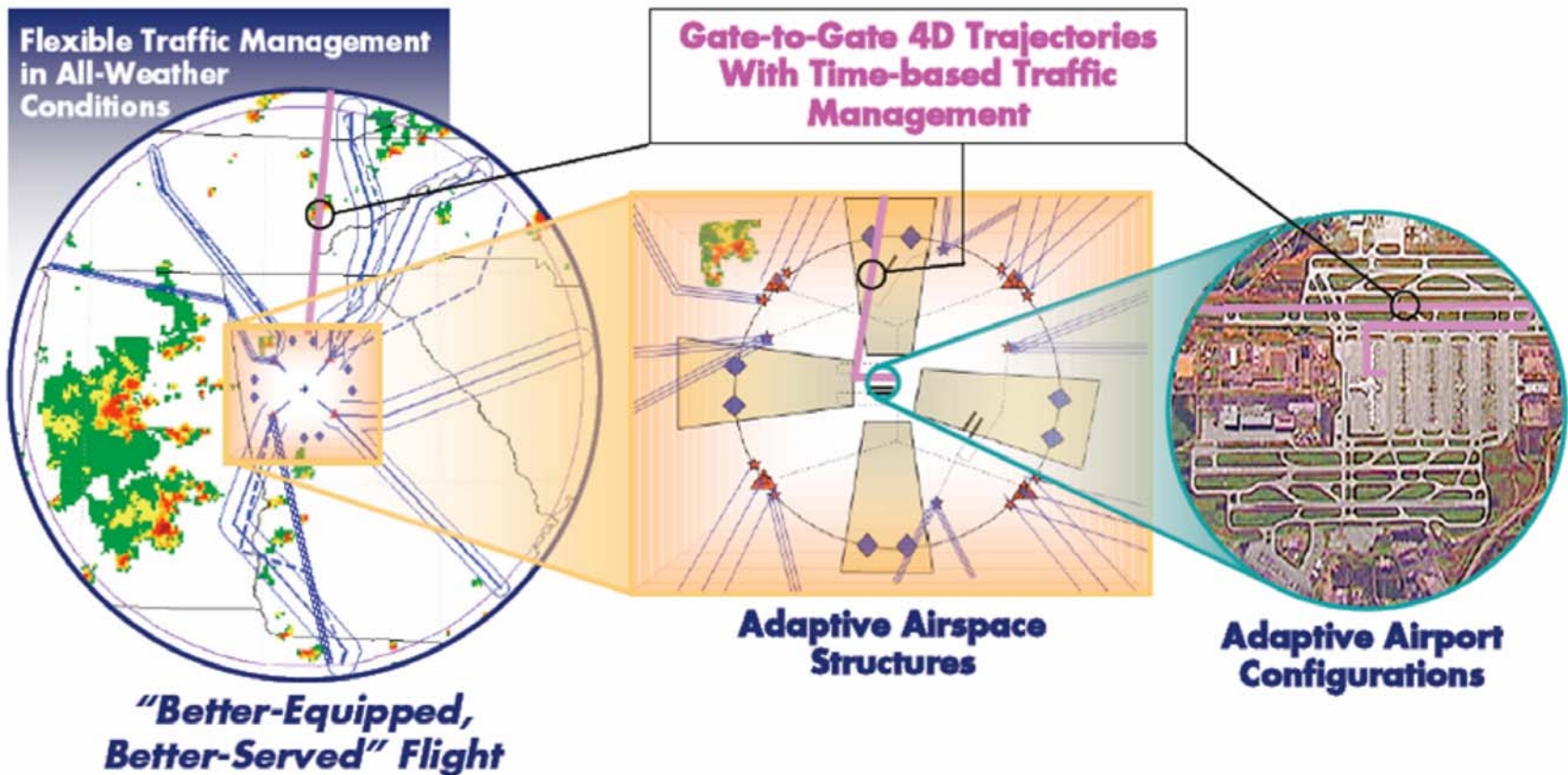
### Foundational Research

- Airspace complexity and equity metrics  
(NRA: Massachusetts Institute of Technology, PI Dr. R. John Hansman)
- Optimum timing for reconfiguration
- Optimization schema and approaches for airspace configurations  
(NRAs: Metron Aviation, PI Dr. R. Hoffman, Mosaic ATM, Inc., PI Mr. C. Brinton, CSSI, Inc. PI Dr. M. Rodgers)



# Increased Capacity through Dynamic Airspace Configurations

## Some Examples





# Airspace Project – Research Area

## Traffic Flow Management



### Problem

- Equitable and Efficient optimization of constrained airspace resources
- High volume and large mix of aircraft characteristics and users of the airspace

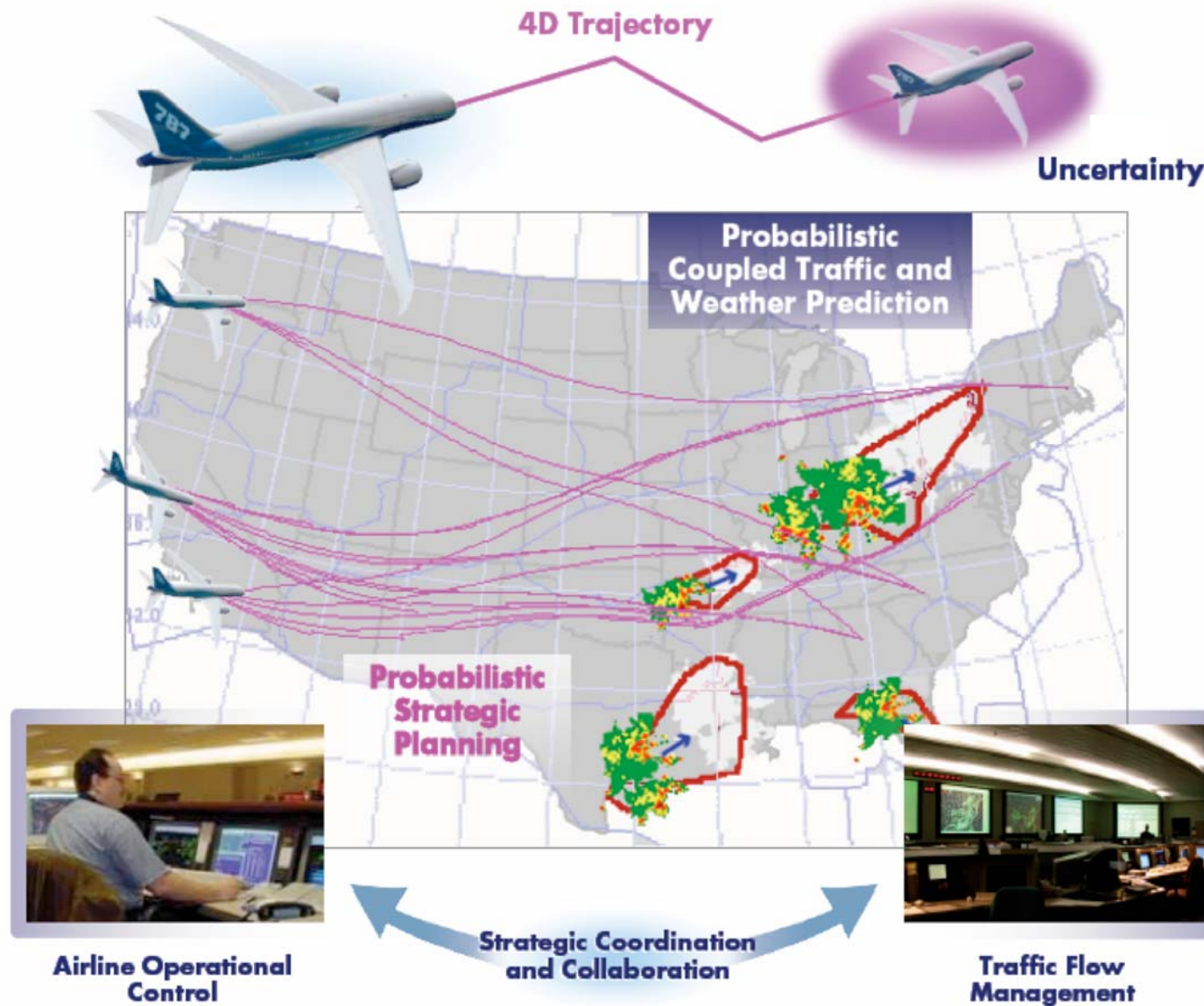
### Expected Impact or End Result

- Multi-Aircraft Trajectory Control to minimize system constraints and maximize system utility
- Provide minimum disruption control (or no control) over the appropriate time horizon
- Adaptive to uncertainty (weather, demand)

### Foundational Research

- Use of both individual and aggregated trajectories  
(NRA: Washington State University, PI Dr. Sandip Roy, Optimal Synthesis Corp., PI Dr. P.K. Menon, University of California, Berkeley, PI Dr. M. Hanson)
- Optimization (organize, schedule and regulate) based on user needs and airspace constraints  
(NRAs: University of Maryland, PI Dr. Mike Ball, Georgia Institute of Technology, PI Dr. John-Paul Clarke, L3 Communications, PI Dr. H. Idris)
- Understanding and modeling weather impacts/constraints  
(NRAs: Metron Aviation, PI Dr. J. Krozel, Mosaic ATM Inc., PI Ms. L. Cook)
- Constraint prediction, deterministic & probabilistic  
(NRA: University of California, Berkeley, PI Dr. A. Bayen)

# National and Local Traffic Flow Management through Probabilistic Strategic Planning



# Airspace Project – Research Area

## Automated Separation Assurance



### Problem

- Human control of separation assurance limits the capacity of the airspace
- Lack of ATM procedures that leverage emerging airborne technologies

### Expected Impact or End Result

- Development of architectures, systems and algorithms to assure multi-aircraft separation and trajectory control
- Tested under full regime of cruise and transition operations including off-nominal and system, sub-system failure and recovery

### Foundational Research

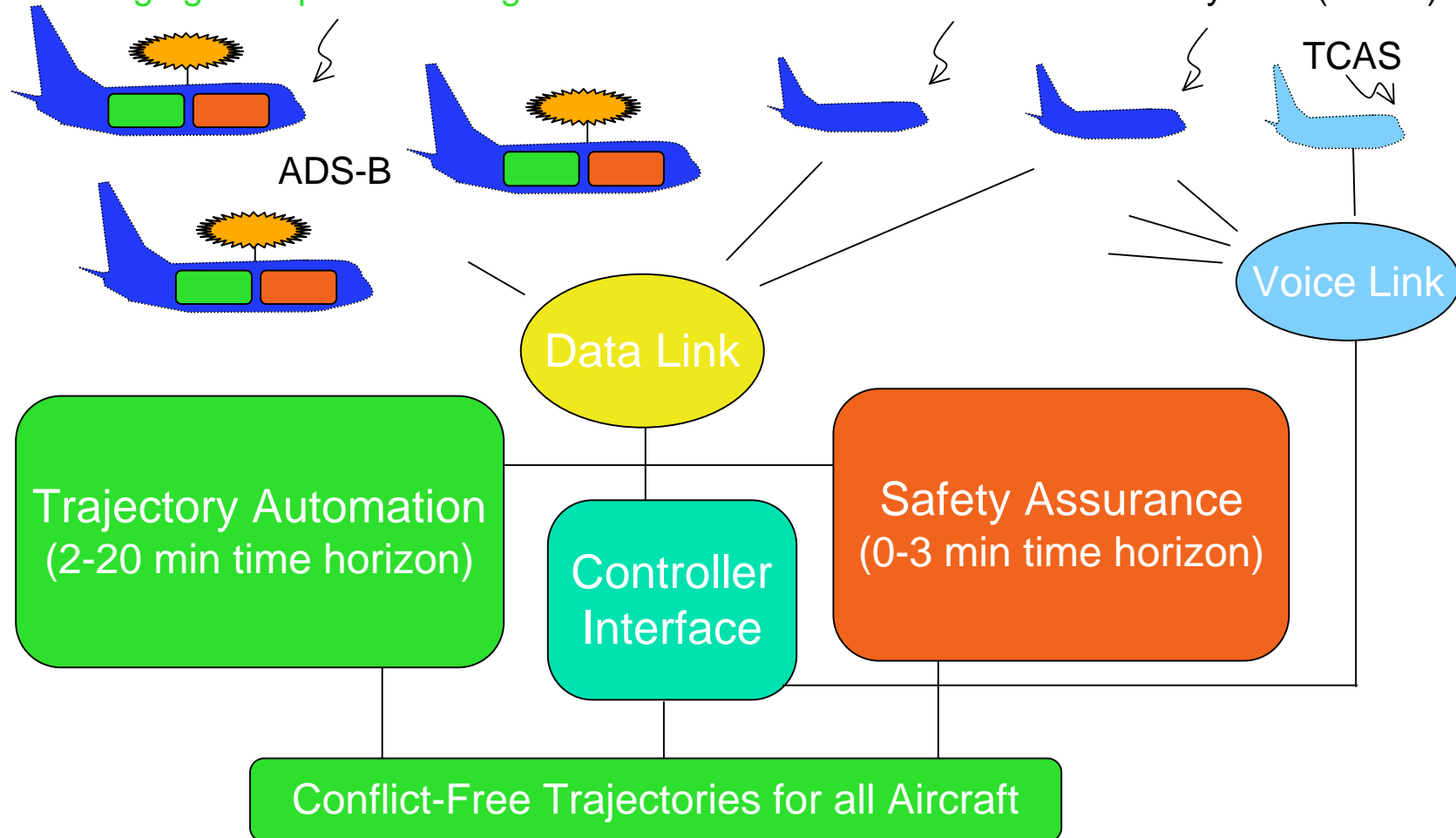
- Technology and procedures that ensure safety under ALL conditions  
(NRAs: University of California, Santa Cruz, PI Dr. H. Erzberger  
Purdue University, PI Dr. S. Landry)
- Separation Assurance in the presence of TFM goals
- Separation assurance and collision avoidance algorithm compatibility  
(NRA: Stanford University, PI Dr. C. Tomlin)

# Elements of Automation Safety Architectures for a Future High Capacity Airspace System

(Air Navigation Service Provider Perspective)



Emerging Cockpit Technologies + Traffic Alert & Collision Avoidance System (TCAS)

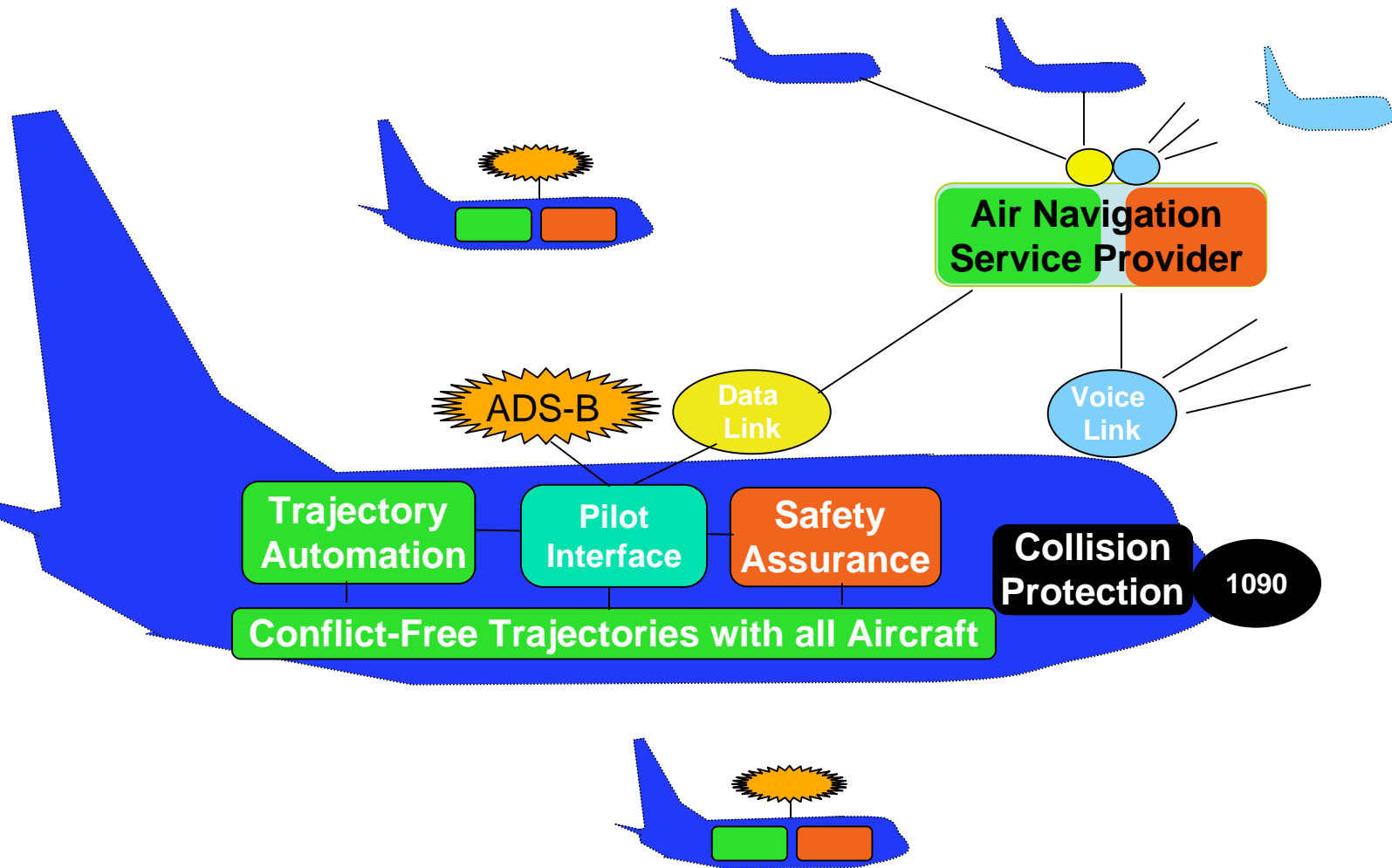


# Elements of Automation Safety Architectures for a Future High Capacity Airspace System

(Highly Equipped Aircraft Perspective)



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# Airspace Project – Research Area

## Airspace Super Density Operations



### Problem

- Human control of separation assurance limits the capacity of the terminal airspace
- Lack of scalability of closely coupled runway resources

### Expected Impact or End Result

- ConOps definition
- Development of multi-objective sequencing, merging and de-confliction
- Development of precision spacing and merging technologies extended to environmental trajectory optimization
- Scalable technologies for regional and metroplex airport use (significant Airport interaction)

### Foundational Research

- Algorithms that solve/optimize simultaneously the sequencing, merging, de-confliction and spacing

(NRAs: **Massachusetts Institute of Technology, PI Dr. R. J. Hansman**  
**Metron Aviation, PI Dr. J. Krozel**)

- Provably safe close trajectory maneuvers, algorithms and architectures
- Regional resource utilization

(NRAs (joint with Airport): **Georgia Tech., PI Dr. J.P. Clarke, George Mason University, PI Dr. G. Donahue, Mosaic ATM Corp. Dr. S. Atkins**)

- Multi-aircraft heterogeneous “mixed” aircraft type environmentally compatible trajectories close to runway goals

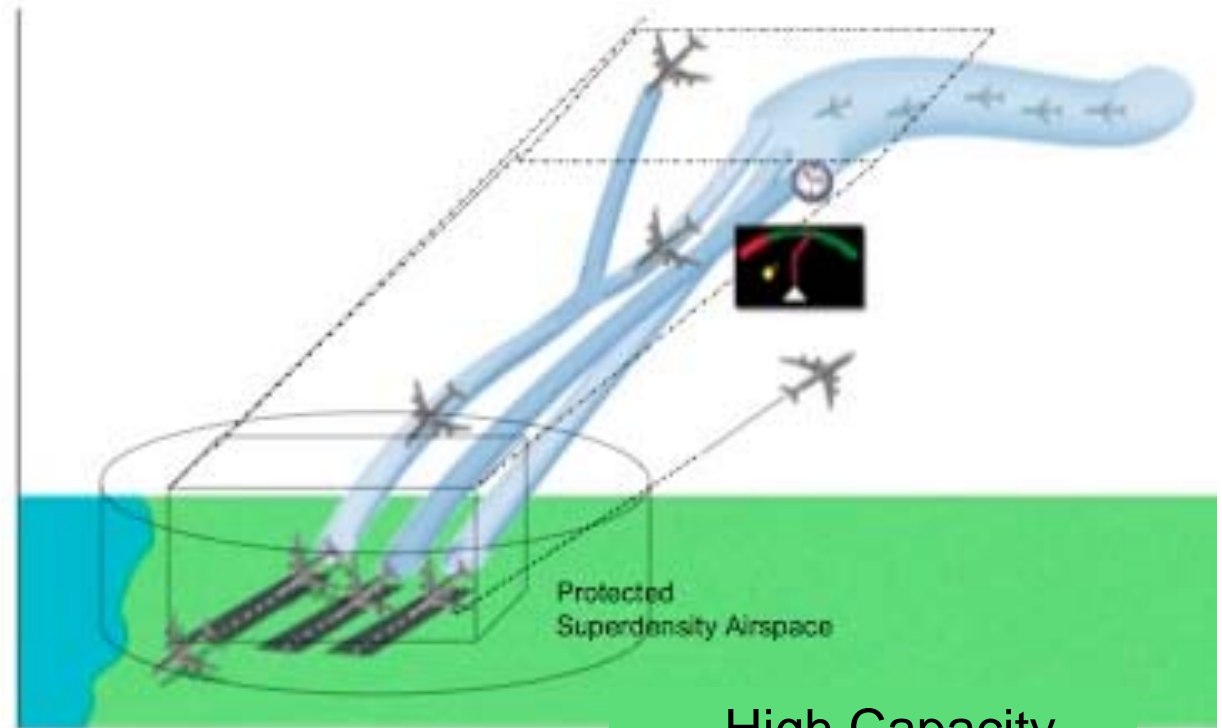


# Airspace Super Density Operations Concept Snapshot



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- Dynamic Required Navigation Performance routes/flows
- Very closely spaced runway operations
- Reduced separation standards
- Stochastic schedule multi-objective optimization
- Airborne precision spacing
- Integrated arrival/surface/departure operations
- Coordinated management of 4D trajectories for user and terminal system objectives (e.g. order preference vs. schedule robustness)



High Capacity  
Robust  
Efficient  
Responsive  
Safe  
Secure  
Affordable

# Airspace Project – Research Area

## Trajectory Synthesis Prediction and Uncertainty



### Problem

- Lack of interoperability of trajectory prediction techniques
- Lack of functional specific requirement and standards
- Lack of trajectory prediction techniques for complex and off-nominal trajectories

### Expected Impact or End Result

- Development of ATC and Flight Deck Interoperable trajectories
- Trajectory prediction standards
- Development of control strategies that account for the uncertainty and ensure flexibility
- Development of trajectory complexity measure (complementary)

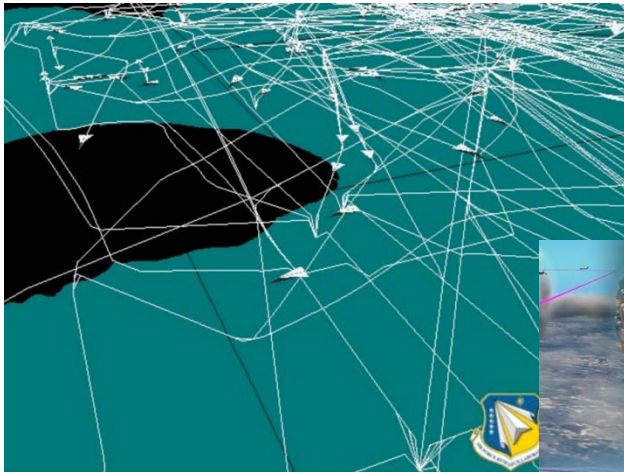
### Foundational Research

- Trajectory predictions accuracy as a function of time, model parameters, meteorological effects and aircraft intent modeling  
(NRAs: L3 Communications Titan Corporation, PI Mr. R. Vivona, L3 Communications Titan Corporation, PI Mr. R. Vivona, University of Minnesota, PI Dr. Y. Zhao)
- Probabilistic trajectory control  
(NRA: L3 Communications Titan Corporation, PI Dr. H. Idris)

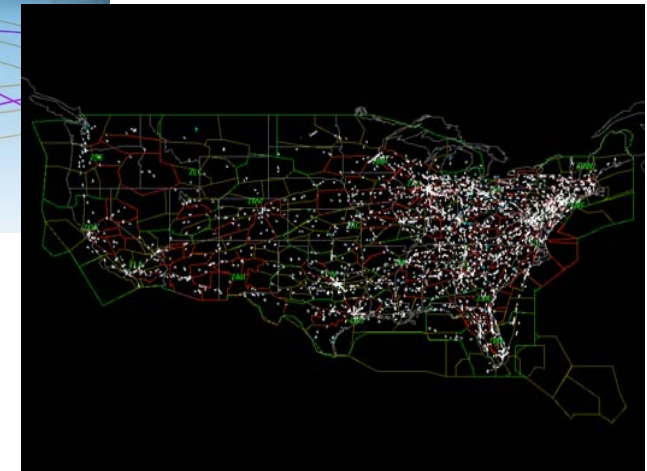
# Transitioning ATM from Airspace-Based to Trajectory-Based Operations through Trajectory Prediction and Analysis



## Trajectory Prediction



Local - Deterministic



Nationwide - Stochastic

# Airspace Project – Research Area

## Performance-Based Services



### Problem

- Unrealized performance gains by investment in emerging airborne ATM technologies
- Paradigm shift from technology certification to performance certification

### Expected Impact or End Result

- Development of performance attributes of the elements of NGATS
- Development of a performance based hierarchy
- Case studies of air-based, ground-based, and mixed-separation assurance approaches

### Foundational Research

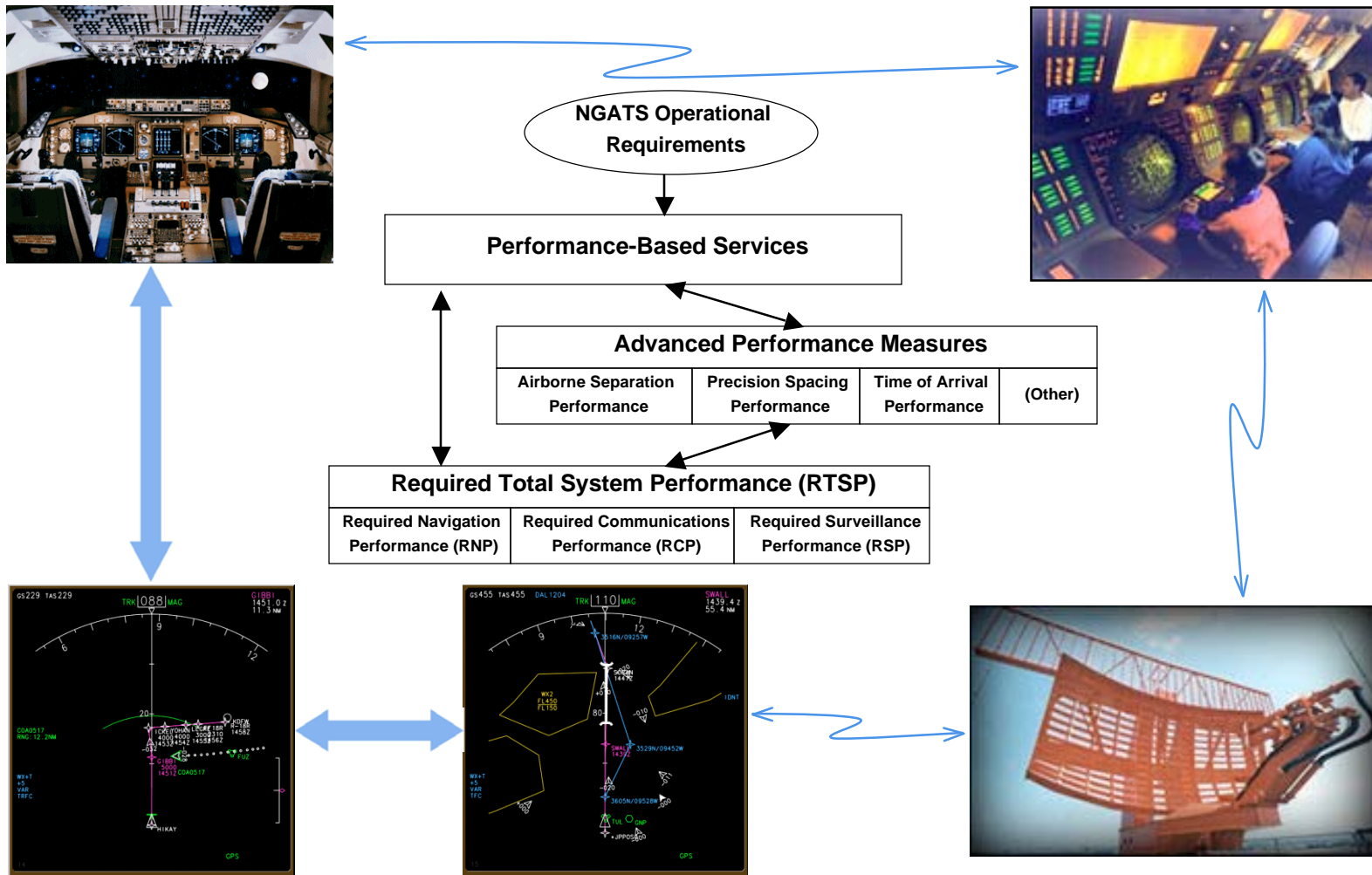
- Relationships between emerging airborne technologies and airspace performance requirements  
(NRAs: Georgia Tech., PI Dr. A. Pritchett, CSSI Inc., PI Dr. S. Mondoloni)
- Methodologies to define performance requirements from capability descriptions

(NRA:IAI Inc., PI Dr. V. Manikonda)

# Service Provider Service Levels Matched to User Performance Capabilities through Improved Performance-Based Services



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# Airspace Project – Research Area

## System-Level Design, Analysis, and Simulation Tools



### Problem

- The NAS is a complex system which evolved based on technology availability and emergency response to failures
- The future needs to be designed with analyses and design attributes
- Lack of airspace design tools that don't mimic today's design

### Expected Impact or End Result

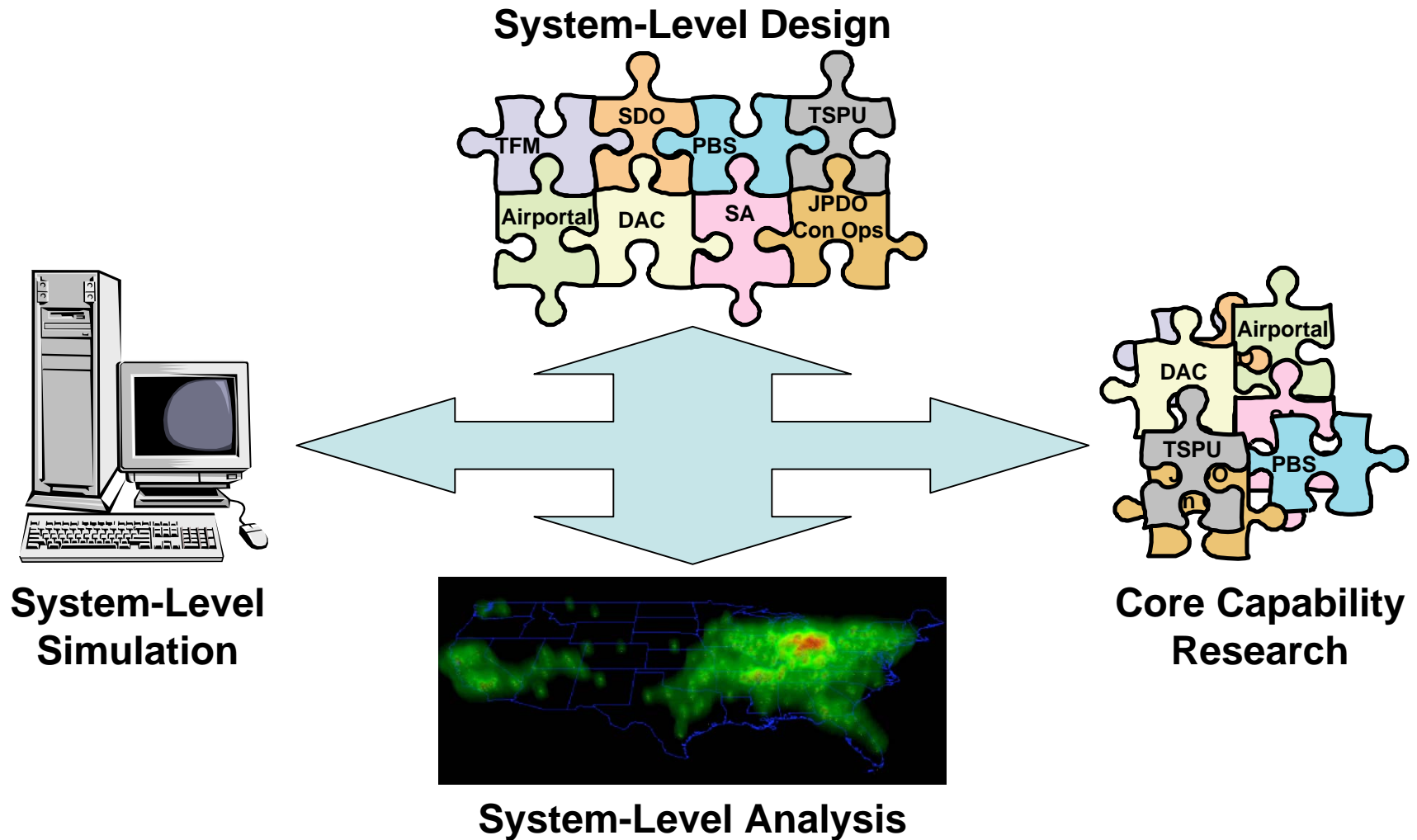
- System analysis of integrated core thrusts including Airportal advancements
- Allocation analysis of DAC, TFM, SA, and ASDO advances
- System trade studies
- System validation and certification

### Foundational Research

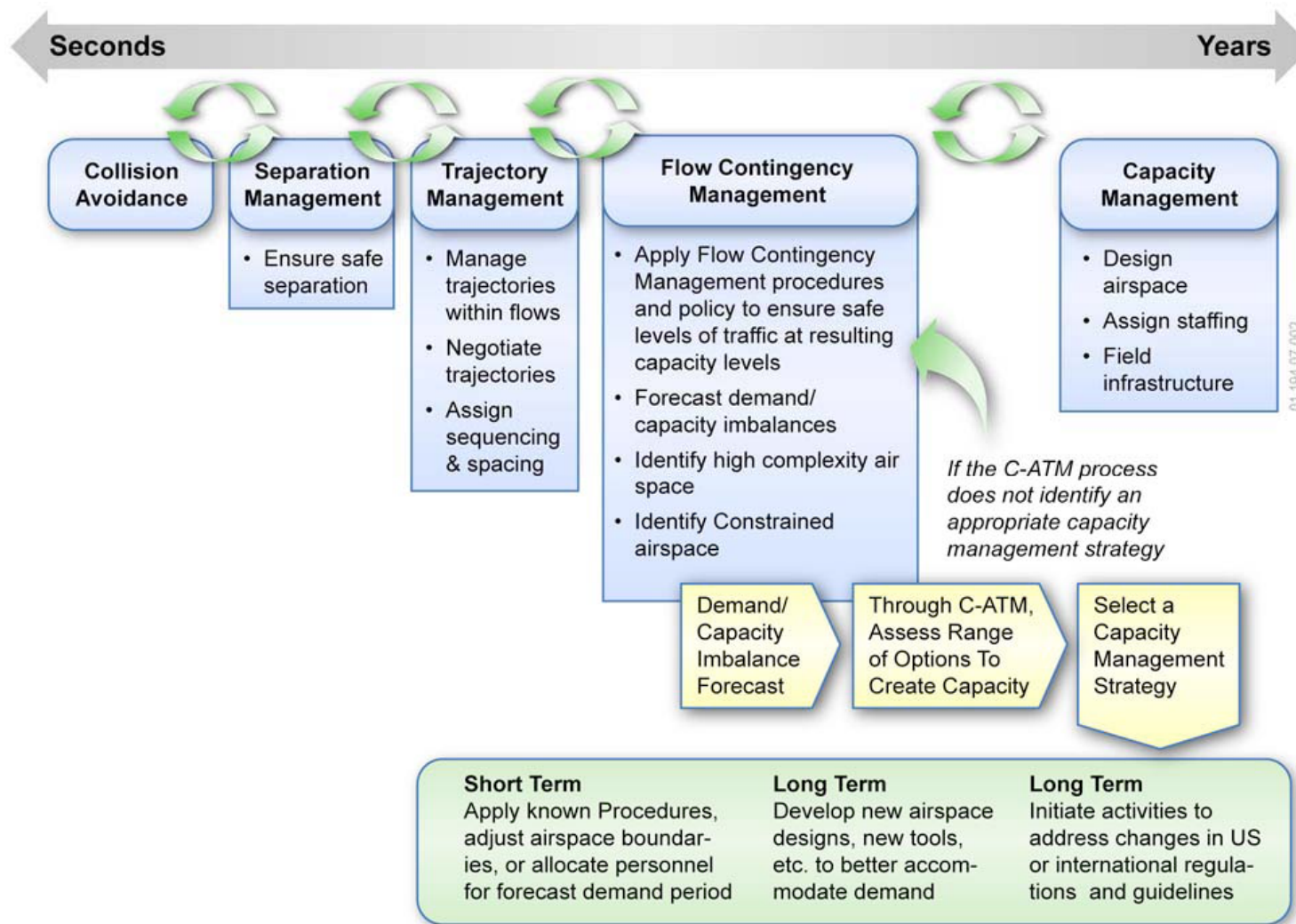
- Detailed concept design
- Agent representation of ATM functions
- Modeled Human performance  
(NRA: San Jose State University, PI Dr. K. Corker)
- Design metrics and optimization trade algorithms and tools  
(NRA: George Mason University, PI Dr. L. Sherry)



# Coordinated Research Success through System-Level Design, Analysis, and Simulation Tools

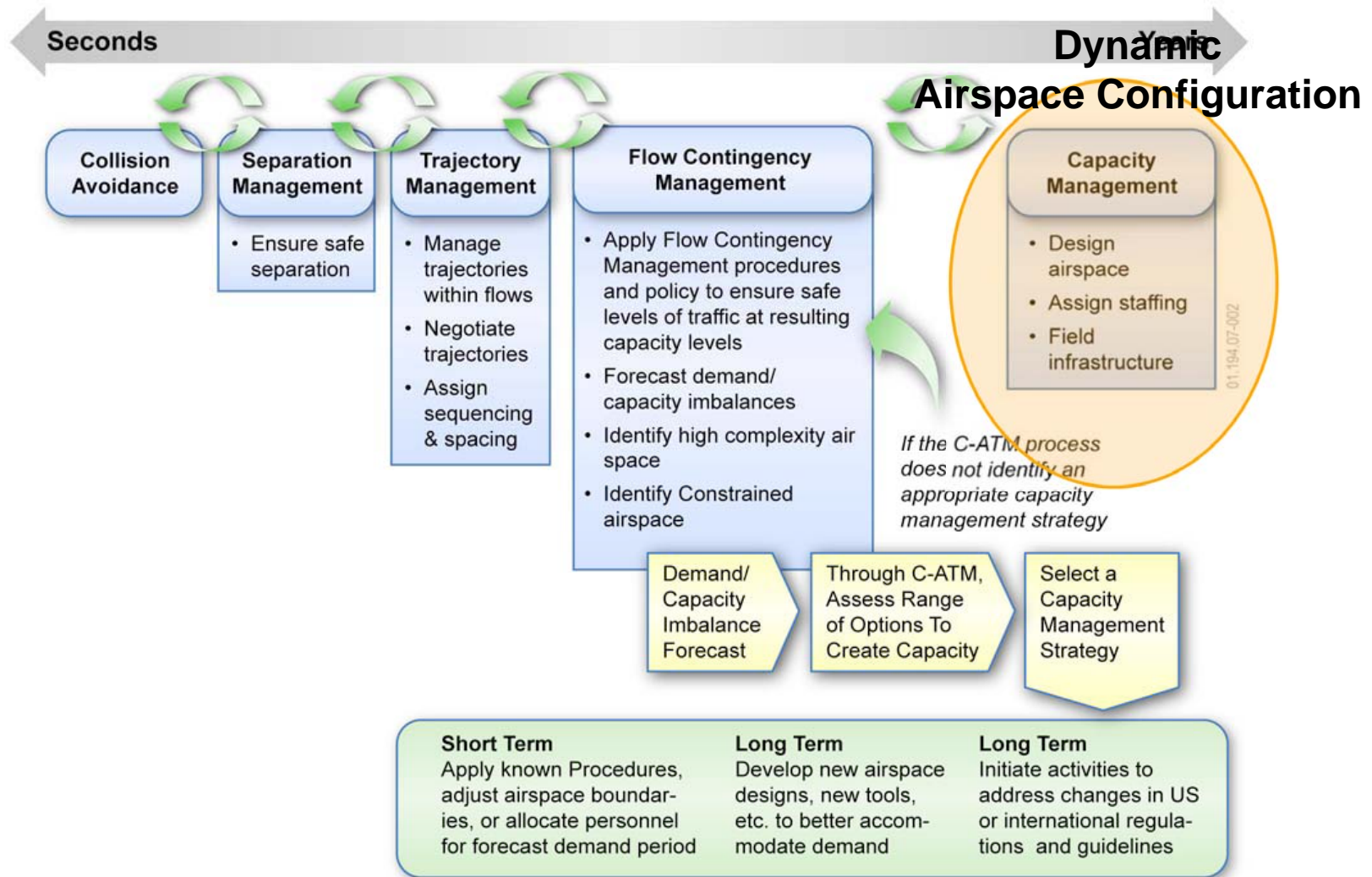


# Elements of Automation for a Future Airspace System



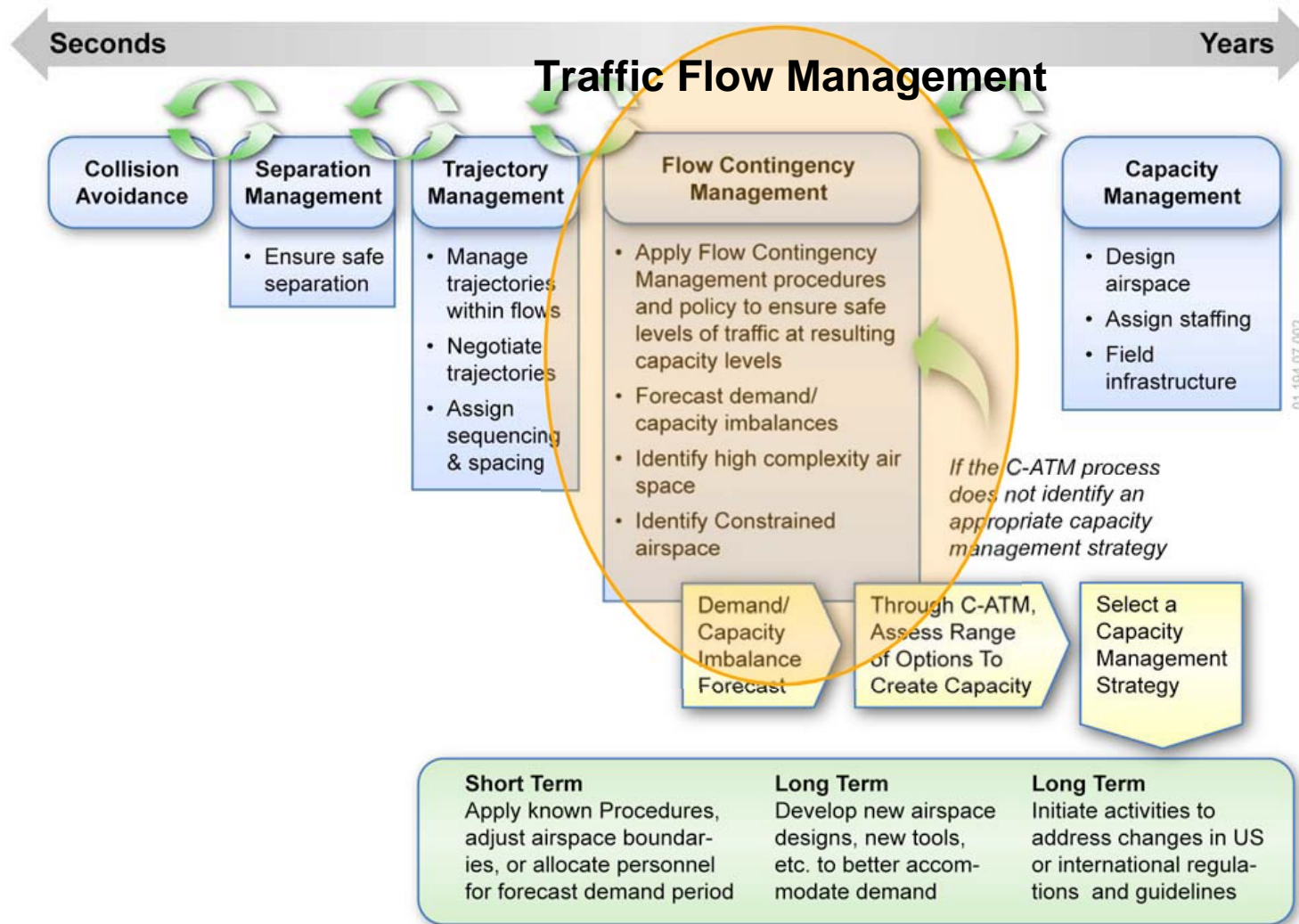
Ref: Figure 2-2 "ATM Decisions-Interactive and Integrated Across Time Horizons" JPDO Concept of Operations for the Next Generation Air Transportation System Draft 5 V 1.2 Feb. 28, 2007.

# Elements of Automation for a Future Airspace System



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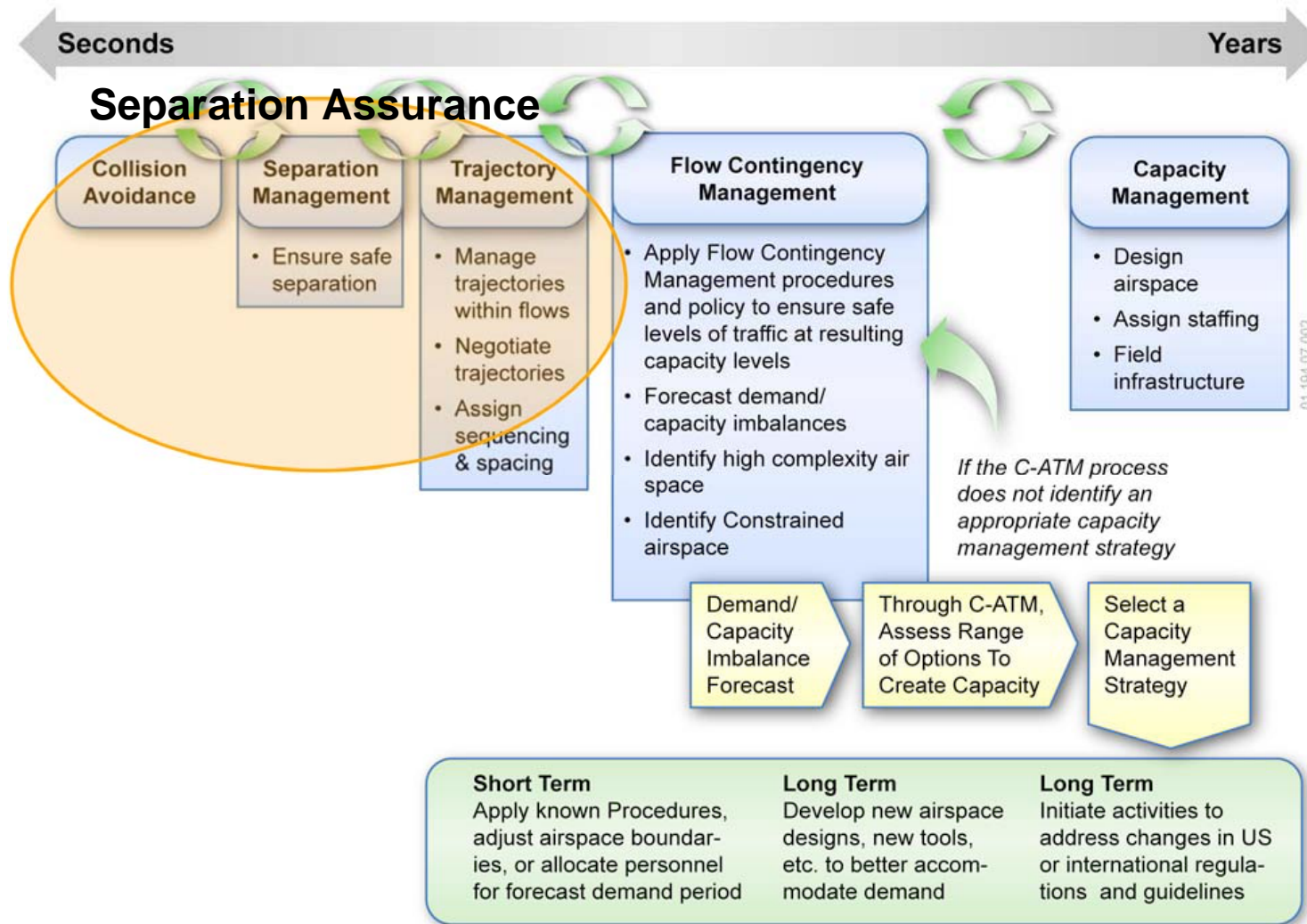
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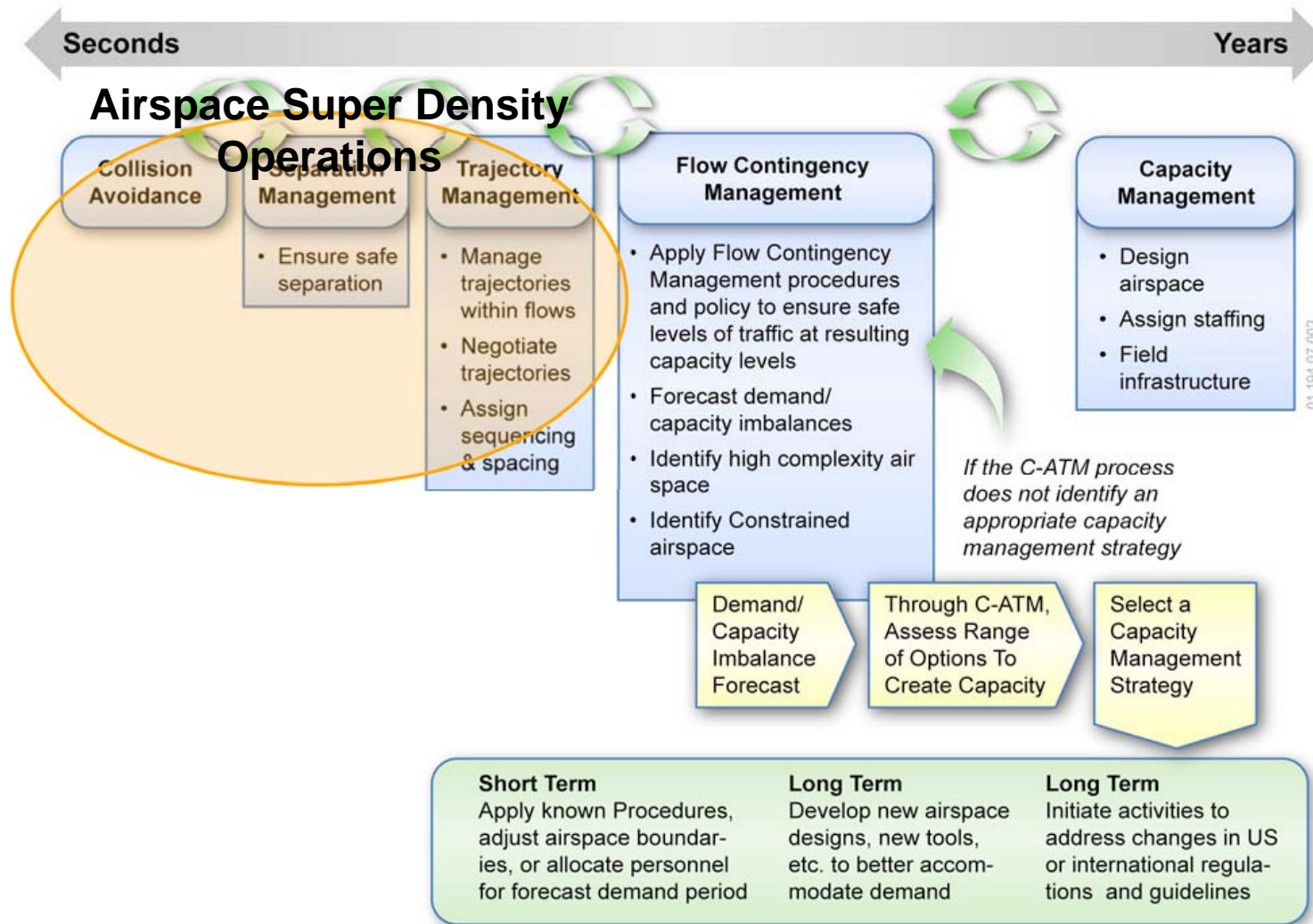


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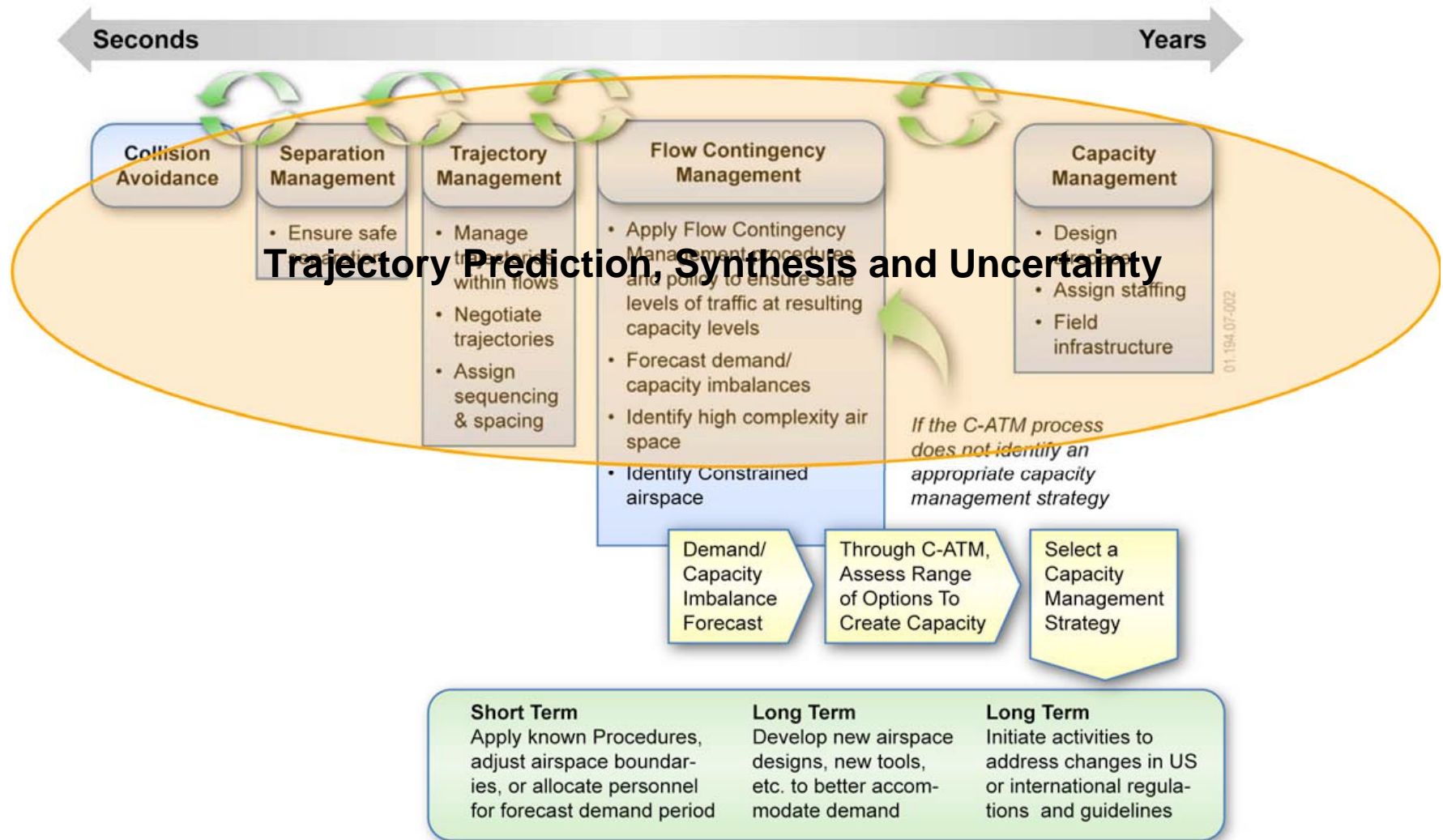
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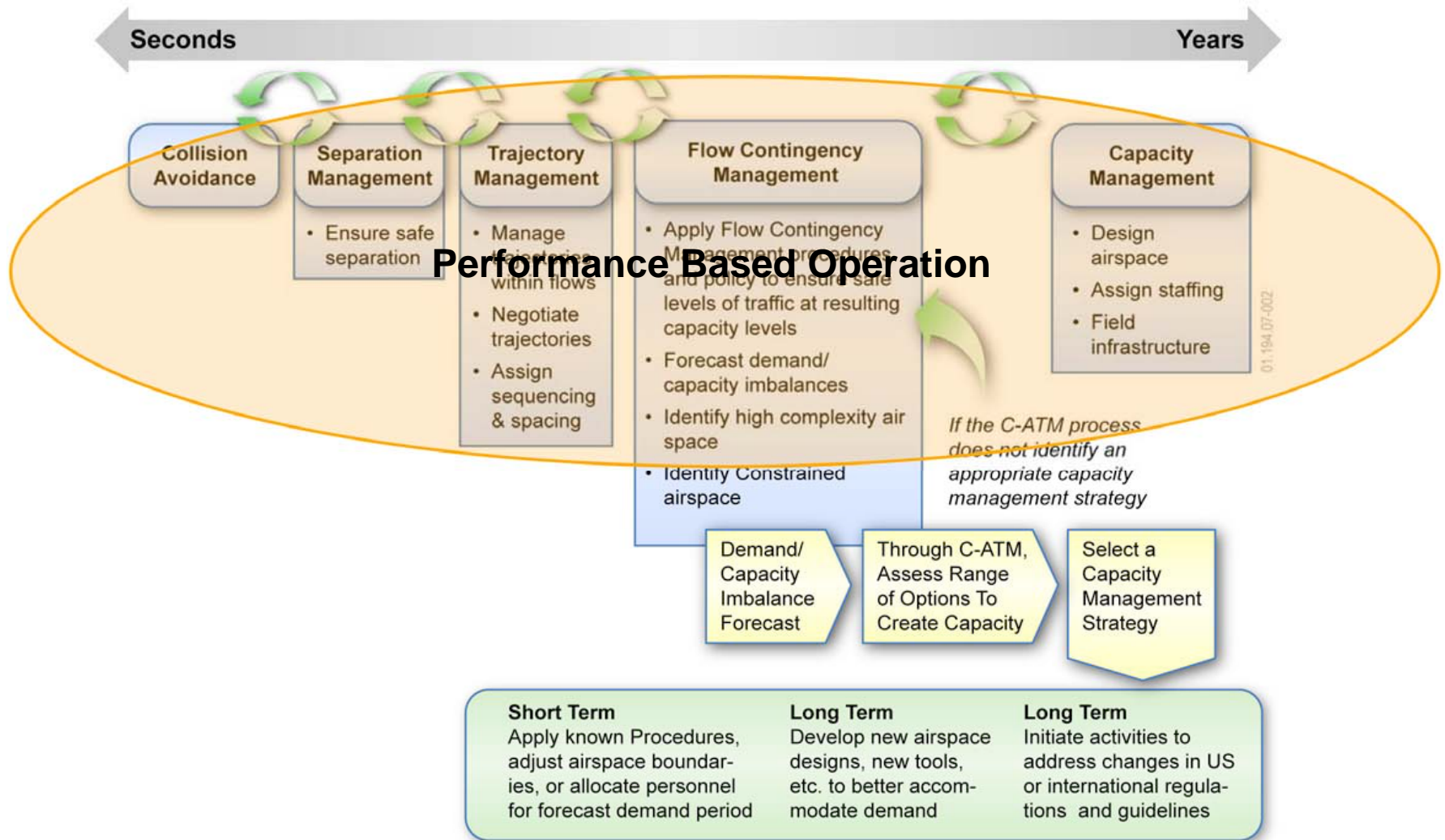


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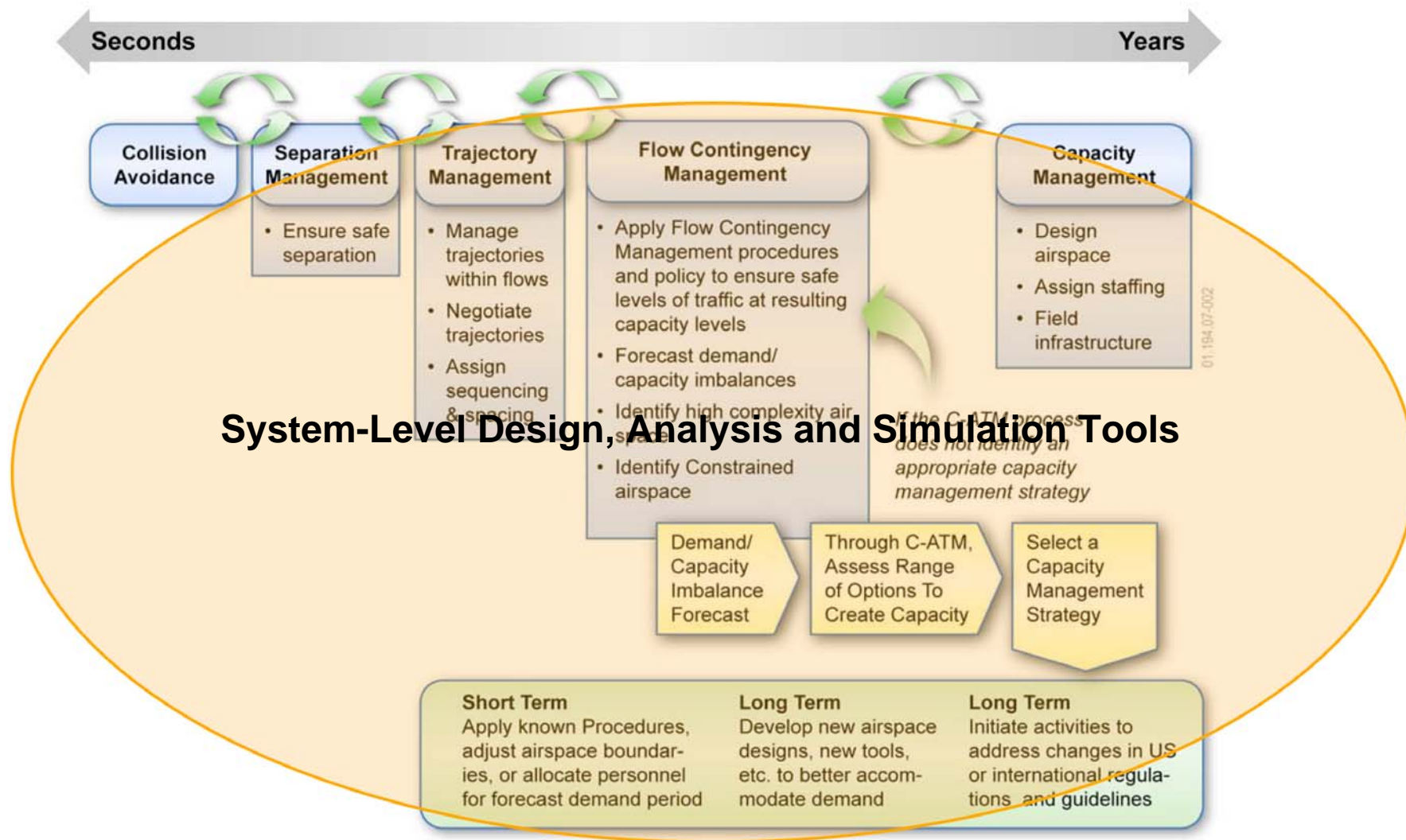


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## Future Growth Areas



- **Weather impact analyses on airspace and automation design**
- **Multi-Vehicle system safety analyses**
- **Off-nominal condition scenario development**
- **Complex system design methodologies**
- **Desired performance attributes of future vehicles**



# Discussion

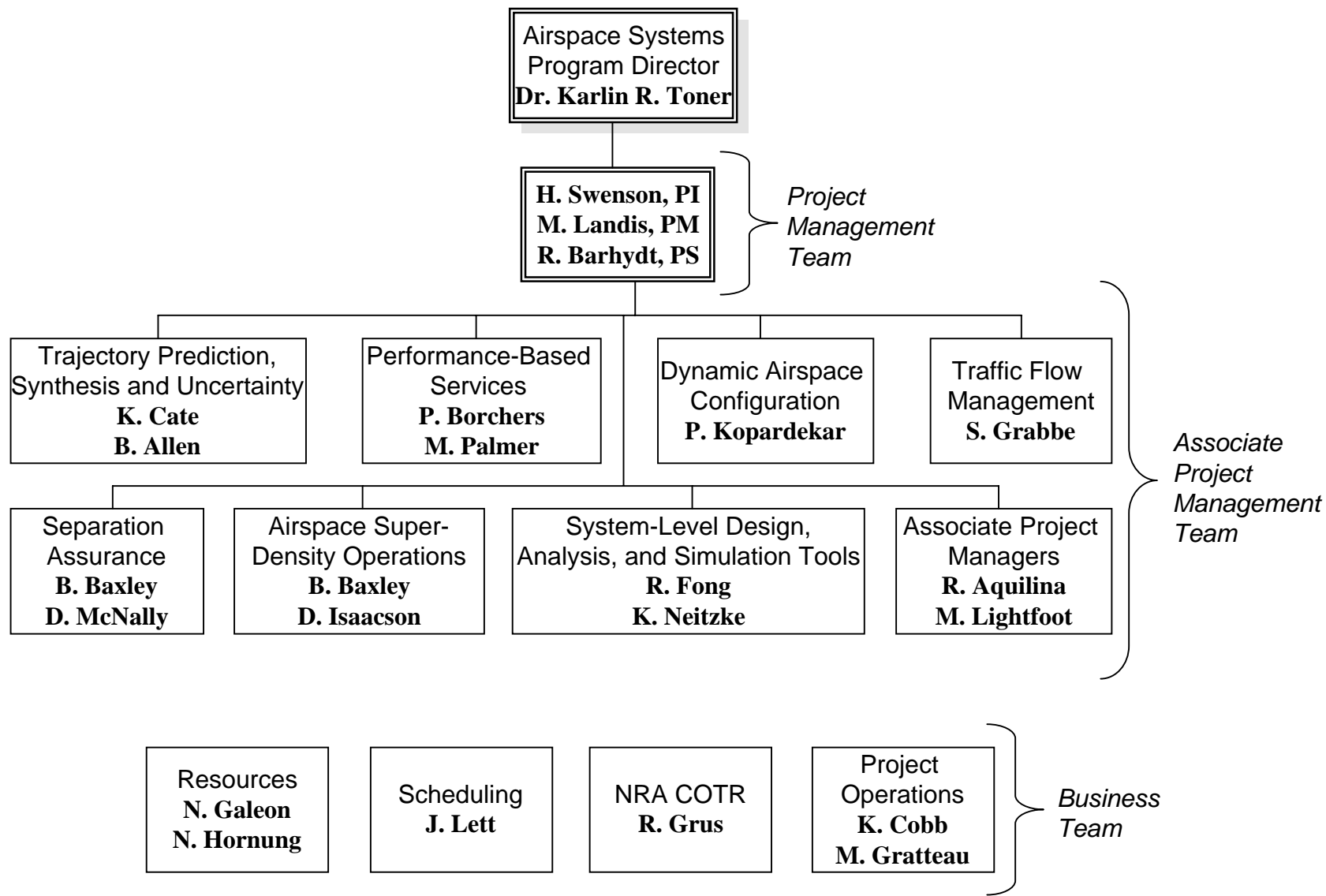




# BACKUP



# Airspace Project Technical Organization



## Summary

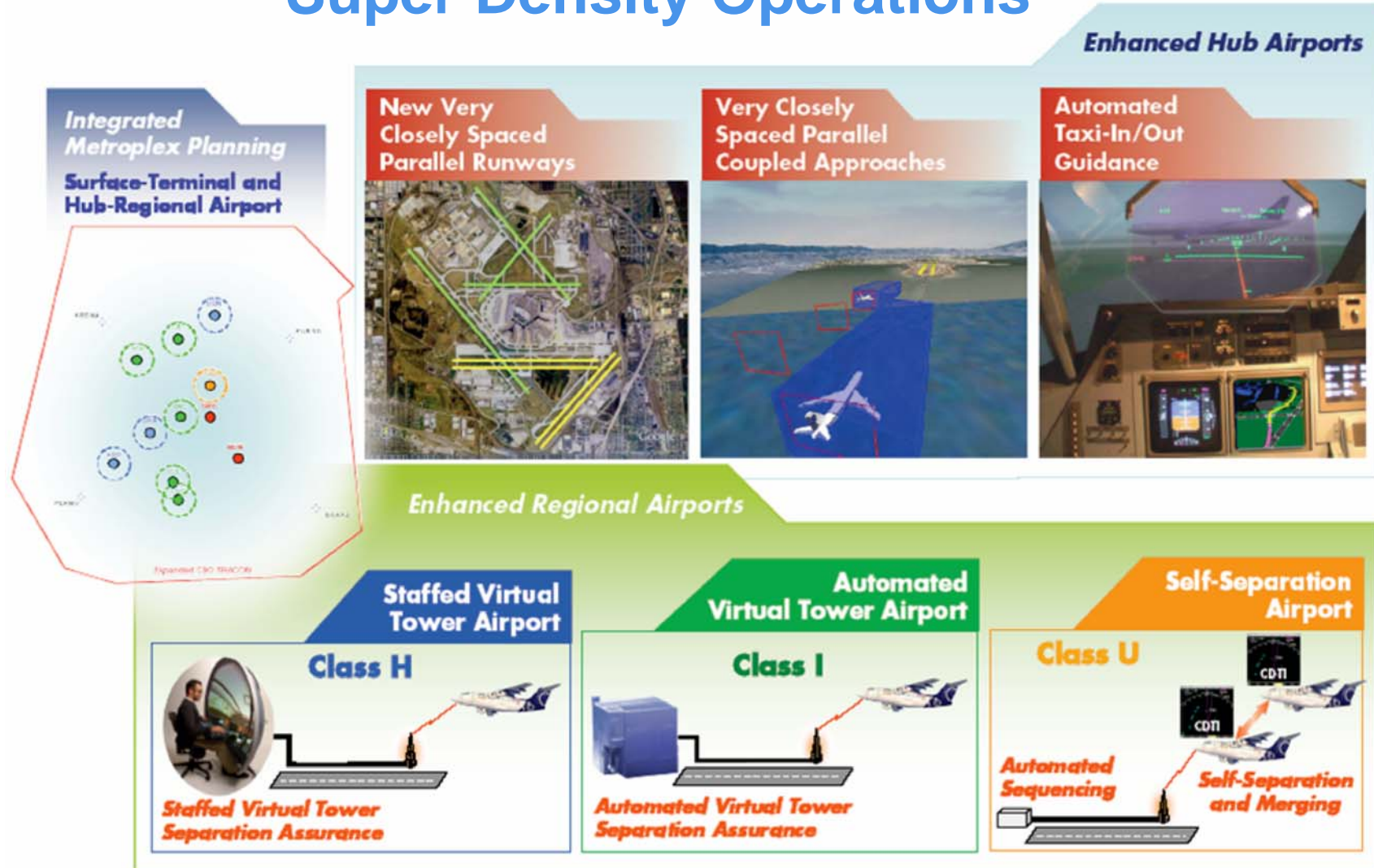


- **NASA is dedicating its efforts to the mastery, intellectual stewardship, and technical excellence in the field of Aeronautics.**
- **The NASA NGATS research portfolio will contribute to the foundational sciences: Computer Science, Applied Physics, Automation Design, Applied Mathematics for System Optimization, and Human Factors.**
- **The thrust and cross-cutting research in Airspace Design, Traffic Flow Management, Separation Assurance, Trajectory Synthesis, Performance Modeling, Surface Optimization, and Systems Analysis will enable NASA to contribute to the long-term needs of the Joint Planning and Development Office (JPDO)**

# Reduced Aircraft Separation in All-Weather Conditions through Advanced Ground and Air Technologies Providing Super Density Operations



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